THE HETEROGENEOUS IMPACT OF PUBLICLY FUNDED R&D ON FIRM R&D INVESTMENT, INNOVATION AND ECONOMIC PERFORMANCE: THE ITALIAN CASE

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CORPORATE R&D: AN ENGINE FOR GROWTH, A CHALLENGE FOR EUROPEAN POLICY

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IMPACT OF R&D ON FIRM PRODUCTIVITY AND MARKET PERFORMANCE

Abstract

The objective of this paper is threefold: first: we identify econometrically the presence/absence of "own R&D" investment additionality/crowding-out within a pooled sample and in various subsets of firms (by regional, dimensional, technological and other characterizations), taking into account the effect of "single" as well as of "mix" of policy instruments. Compared to previous R&D policy evaluation studies (see the review by David et al., 2000 and Cerulli, 2009), focusing mainly on the estimation of a single causal effect-parameter, we (also) provide an estimation of the "entire distribution" of the FAR "treatment effect" according to the observed firms' "heterogeneity": we identify the group of firms performing "additionality" and that performing "crowding-out" comparing the "structural characteristics" distinguishing the two groups of firms in order to appreciate which are the factors driving to the success/failure of FAR;
second: we explore the analysis of the FAR effect on the output (i.e., "innovation") additionality (OECD, 2006) by comparing the differential impact of "privately funded" (firm own resources) and "publicly funded" industrial R&D expenditures on the number of patents filed by firms. We use a "two steps" procedure (Crèpon et al., 2008; Czarnitzki and Hussinger, 2004): in the first one, we apply a Nearest Neighbour Matching (Cerulli and Potì, 2008) to calculate the "own R&D additional component", in the second step we perform a Poisson (multiple) regression of the number of patents on firm own R&D, on subsidy and on the "additional own R&D" as calculated in the first step. If the "additional component" takes a positive and significant value, we should conclude that the considered policy has been successful also on the side of firm innovative performance;
third: we finally try to explore the last R&D supporting effect, that coming from innovation to firm economic performance by three indicators of: productivity, profitability and rate of growth. In this case we use again a comparison between the additionality and crowding-out group using results from the analysis performed above. Although the limited time span we consider (five years), an inspection into performance effects seems of worth per se.

Key words: R&D and innovation policy, econometric evaluation, firm performance
JEL classification: O32, C52, O38

TABLE OF CONTENTS

LIST OF ANNEXES

1 - Introduction

The paper explores the impact of a specific R&D policy tool, the Italian Fondo per le Agevolazioni della Ricerca (hereafter FAR), on industrial R&D and technological output at firm level, exploiting some results of a three years national strategic research project funded by the Italian Ministry of Research (FIRB 2005-2008, cod. RBNE03ETJY).

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Before presenting data, methodology and results we begin the paper with two theoretical sections: the first explaining why it seems useful and needed to support R&D and innovation from a public agency perspective, the second providing a general theoretical framework to understand how and in which direction a subsidy affects firm R&D and innovation performance.

2 - The rationale for R&D subsidization

What is the rationale for R&D subsidization? Neoclassical theory based on a positive externality argument suggests that, because of the public good characteristics of the R&D activity, the level of private R&D expenditure would be systematically lower than the socially optimal level (Arrow, 1962). This occurs since the benefits associated to R&D activities are easily and freely available to subjects that are not engaged in R&D efforts . Indeed, the lack of full appropriability of R&D outcomes reduces the incentive to do R&D on the side of private for-profit firms so that, as in a classical Pigouvian context, a government intervention through subsidization can reduce the extent of this "market failure".

This argument has been widely criticized by several scholars. From an evolutionary perspective, for example, Cohen and Levinthal (1989) have argued that knowledge cannot be so easily absorbed unless imitative firms invest in their turn on a certain level of R&D effort: imitation is not costless and needs for some preexisting R&D activity's "hard core" . This standpoint could convey a paradoxical consequence: in an environment characterized by a great amount of spillover effects firms could have greater incentives to perform R&D since, in doing so, they might enlarge their absorptive capacity, i.e., their ability to benefit from others' R&D efforts. In this way, they could more easily imitate and exploit market surpluses. Paradoxically and as a consequence, the level of R&D could be too high (rather than too low), since many firms could undertake too much R&D effort than that required to reach the same social results (for example, by an increase of duplications in R&D expenditures).

From another perspective, also the New Industrial Organization theory, in its "patent race" version (Dasgupta and Stiglitz, 1980; Dasgupta, 1988; D'Aspremont and Jacquemin, 1988) arrives to conclusion quite different from the standard basic neoclassical model. Indeed, when a number of firms in a given industry compete to obtain a patent allowing a lifelong monopoly power, they can bear costs that could not be recovered once the race has been lost. In such a case many R&D expenditures do not lead to innovation and industrial exploitation, in so representing a cost for the society as a whole (with duplication of R&D efforts, or losses due to asset specificity allocation). As a conclusion the R&D effort could be excessive for the society and cooperative alternatives (such as research joint venture or other cooperative strategies) could lead to welfare improvements.

Other scholars, on the contrary, have suggested that R&D should not be taken as a pure public good: a firm has a great amount of tools to protect its inventive capacity, such as patents, secrecy, and so on (see, for example, Nadiri, 1993). Therefore, the extent of positive externalities' production can be very limited and/or industry specific and the need for supporting R&D activity more controversial than it can appear at first glance.

Nevertheless, as many authors have maintained, the need for subsidization, other than that due to positive externalities, can be invoked since other market failures can be at work such as: 1. imperfect markets of capital, 2. missing markets for high-risk investments (such as undersized venture capital markets), 3. too high barriers to entry and exit, 4. excessive market power or, on the contrary, excessive fragmentation of market power, 5. lack of technological infrastructures and bridging institutions, 6. coordination failure of profitable R&D joint venture, producing duplications in R&D efforts and other resource wastes, and so on (see, for a general discussion on these points: Martin and Scott, 2000). In the first case, the failure can arise because R&D investment could be too risky and asymmetric information between lenders and borrowers too high, generating in that way high funds' rationing; in the second case, financial markets and instruments could be not enough

developed to provide resources to highly innovative ideas and technologies; in the third case, instead, imperfect competition due to barriers such as too high fixed costs to enter the market and/or too high costs to get out (sharp "sunk costs"), can produce a sub-optimal level of R&D expenditure; in the fourth case, the market structure and firms' size determine the industrial R&D performance according to the complex system of incentives this market structure induces also at different sectoral level ; the fifth and sixth cause, finally, could depend on scarce material and immaterial knowledge infrastructures and on various "traps" in the functioning of the national system of innovation (Mowery, 1995; Metcalfe, 1995; Malerba, 1993).
As to spillovers, one important aspect that should be taken into account is what type of effect a subsidy can generate in their presence. As suggested by Klette, Møen and Griliches (2000), in fact, a subsidy can in its turn generate additional spillover effects, so that non-subsidized firms can profit from the R&D effort undertaken by subsidized firms. This fact generates another paradoxical conclusion: one uses a subsidy as a tool to internalize positive externality and correct for market failure, while the same subsidy could generate additional spillovers by causing incremental market failure. Actually, and especially in the evolutionary literature, spillovers are invoked more for the "dynamic complementarities" they can generate than for their static (neoclassical) allocation distortion; indeed, since not only "direct" but also "indirect" R&D diffusive effects are at work, subsidies seem to be useful and necessary especially to correct industry dynamic traps.

3 - A theoretical framework to identify the effects of public subsidies on business R&D

The "measurement without theory" long-standing controversy of the econometric discipline seems to have found in the study of the effects of public subsidies on firm R&D expenditure an unexpected revival. The most of the works in this field, in fact, seems to have embraced the only purpose of measuring the presence or absence of "additionality"[1] of public incentives by skipping, at least implicitly, the essential step of going into an explicit theoretical framework explaining this causal relation.

David et al. (2000) and David and Hall (2000) denounced this attitude of the R&D incentive econometric literature and tried to provide more sound theoretical bases for the

[1] The main concern of this review is on "input additionality", that is, the direct effect of an R&D support program on firm R&D expenditure. Nevertheless, and for the sake of clarity, the literature identifies other two kind of additionality: "output additionality" referring to the downstream effect of an R&D incentive on firm innovativeness, productivity or profitability (just to give some output indicators), and "behavioral additionality", referring to the structural/strategical change in the way a firm operate after receiving a subsidy (for example: by becoming a patenting firm, by modifying its technological specialization, and so on). While generally input and output additionality is measured by quantitative-econometric techniques, qualitative surveys (interviews and questionnaires) as well as case-studies are usually used to detect the presence of behavioral additionality (see, for going more in depth on these aspects, the RTD Evaluation Toolbox by the IPTS, European Commission, 2002).

understanding of the effect of public subsidies on R&D private investment[2].

Their structural model identifies the optimal level of R&D investment as the point in which marginal rate of returns (MRR) and marginal capital costs (MCC) associated to R&D investments are equal. This is, on the side of firms, a classical profit maximization strategy. The MRR curve derives from sorting R&D projects according to their *internal rate of return*, as in a usual investment plan. This curve is a decreasing function of R&D expenditures, since firms will first implement projects with higher internal rate of return and then those presenting lower rates. The MCC curve, instead, reflects *opportunity costs* of investment funds, at any level of R&D. This curve has an upward slope due to the assumption that, as soon as the number of projects to implement increases, firms have to shift from financing them by retained earnings to equity and/or debt funding (i.e., from internal to external and more costly sources)[3].

Obviously, both curves depend on a number of variables other than R&D expenditure that can move them either downward or upward. In fact, according to the David et al. (2000) structural model we can write:

[1]
$$\begin{aligned} MRR &= f(R, \mathbf{X}) \\ MCC &= g(R, \mathbf{Z}) \end{aligned}$$

where X and Z are variables that shift accordingly the curves. In particular the X-variables contain some proxies of:

1. technological opportunities;
2. state of demand;
3. appropriability conditions.

Variables contained in Z depend instead on:

1. technological policy tools;
2. macroeconomic conditions;
3. external costs of funds;
4. venture capital availability.

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[2] In particular, they distinguish between *contracts* and *grants*, as they are different incentive tools on the side of the government. In what follows, nevertheless, we will focus primarily on grants, even if many conclusions can be also extended to contracts.

[3] Actually, David et al. maintain that the MCC curve starts with a flat shape becoming increasing only later after a given threshold; this form of the MCC curve is due to the self-financing effect: firms first use retained earnings (flat part) and only after they run them out, they address to the debt and/or equity markets (increasing part). In other words they embraced the “pecking order” approach to firm investment financing (see Myers and Majluf, 1984).

The technological policy tools depend in turn on tax treatment, public subsidies and public-private cost-sharing research projects activated by governmental procurement[4].

The equilibrium condition, *MRR = MCC*, provides the optimal level of firm R&D investment (that we label R^*). In explicit form, in fact, it becomes:

[2] $$R^* = h(\mathbf{X}, \mathbf{Z}) .$$

Provided that X and Z are all exogenous factors, equation [2] is the “reduced form” associated to the structural model [1].

According to this framework we can ask for what kind of effect a subsidy would have to the equilibrium level of the R&D expenditure R^*. If we indicate the amount of subsidy with the letter S and with H the incremental R&D expenditure activated by the subsidy S, we can observe that:

[3] $$R = R^* + H \ ,$$

so that we can outline the following five cases:

1. H = S: no additionality, nor crowding-out occurs;
2. H > S: additionality occurs;
3. 0 < H < S: crowding-out takes place;
4. H = 0: full crowding-out occurs;
5. H < 0 < S: more than full crowding-out takes place.

[4] The distinction among these forms of subsidization is remarkable. In particular, the analysis of contracts differs substantially from that of grants. According to the works of Lichtenberg (1987) and David and Hall (2000) two main elements contribute to the occurrence of additionality/crowding-out effects in the case of contracts: the first relies on the research inputs price increase due to changes in the labour demand for scientists and engineers activated by the contract (especially when the researchers’ total supply is assumed to be fixed and the government is budget-constrained); the second is drawn upon spillover effects generated by contracts especially when they are the bases for future (expected) contracts and/or when they envisage to sell products to the government at the end of the R&D program. Both these causes can bring about additionality as well as crowding-out, even if the first of them (labour market effects) seems more likely to provide ground for crowding-out, while the second (spillover effects) for potential additionality (for a formal model see David and Hall, 2000).

Each of these possibilities can arise and econometric techniques are aimed at detecting which is the case at work in each specific context.

4 - Dataset's construction and features

The R&D supporting program we have analysed in the research project cited in the introduction is the "Fondo per le Agevolazioni della Ricerca" (hereafter FAR) managed by the Italian Ministry of Research that is one of the two main pillars over which national R&D and innovation supporting policies are based (the other pillar is the FIT, "Fondo per l'Innovazione Tecnologica", managed by the Ministry of Economic Development (before Ministry of Productive Activities), that is from 2001 focused on pre-competitive upgrading and marginally on applied research that FAR is intended to promote). FAR is a sort of "mini-mix" policy tool, that is, it contains bottom-up and top-down measures as well as some automatic measures devoted to SMEs. The subsidies consist of standard grants as well as favourable loans and tax credit (Art. 14). FAR contains also that part of the Law 488 devoted to R&D projects in the "Mezzogiorno" area (south of Italy) as well as research programmes co-funded by European FESR and FER (Objective 1, i.e., less developed regions).

We use a database ("panel_Firb" since now) provided by the collaboration among Istat (Italian national institute of statistics), Cilea (an agency working on behalf of the Ministry of Research, hereafter Miur), Confindustria (the main Italian employers' association) and Ceris/CNR (one of the institutes of the Italian National Research Council) driving the FIRB project cited above. Panel_Firb includes information on supported and non supported firms, deriving from the "Anagrafe della Ricerca", a Miur dataset managed by Cilea, where firms planning to apply for Miur project funding have to be registered and where it is indicated if firms received a Miur public support by year. Panel_Firb includes information on the accepted projects (from Cilea) and on firm R&D expenditure by year (from Istat RS1 survey), merged with firm balance sheet accounts (from Istat corporate civil accounts). Our panel_Firb covers a period of five years (2000-2004), when the matching with R&D data (Istat source) was available.

Once the merge among the datasets was realized the sample reduced to 2321 firms observed for five years, that in a first version is in a cross-section form and that we call briefly "panel_Firb_c". In panel_Firb_c the number of supported units is 900 (39%) and that of non-supported units 1421 (61%): for 2/3 of firms there is no public commitment on FAR or LAW 488 projects. Information are collected on financed R&D projects such as their total costs, type of received public aid (grants, favourable loans, tax credit and interest discounted contributions), type of project by specific article and law (LAW 297 bottom-up or top-down project, bottom-up on Law 488, following an automatic procedure, others), project details (project's length, presence of inter firm collaborations, localization in Objective 1 areas, main orientation of the project toward research or development, etc.), as well as some general information on firm (sector, region, number of projects financed, etc.).

Once the panel_Firb_c was shaped in a longitudinal structure, we got the dataset called "panel_Firb" whose main characteristics are shown in table 1. This dataset is the one used in our analysis and deserves some attention. Within it the unit of analysis is the "firm per year" (no longer simply the firm as in panel_Firb_c), so that the number of supported units becomes 1.200 and that of non-supported one 10.405, with a total of 11.605 observations. This increase in supported units depends on the fact that many firms got more than one project accepted within the time span considered (2000-2004). Moreover, since a project generally lasts more than one year, we need to consider a firm as "treated" along all the duration of the project. To be clearer, suppose a firm in 2000 presents a three year financed project, then this firm will be "treated" along all the duration of the project, that is, in 2000, 2001 and 2002 (while not supported in 2003 and 2004, of course). Accordingly, as we will see, the subsidy needs to be "spread on" the project's duration, in so enlarging the number of supported units (remember: firm per year); indeed, once this spreading procedure was done, the number of treated units increased to 1.845 (versus 9.760 non-supported observations) as we see, again, in table 1 and table 2.

Going on reading table 1, we can observe that the public intervention (that is a "gross" measure of the proper intervention, that needs, as we will see, to be calculated according to the "grant equivalent" method) covers on average 49% of the proposed project costs; the average firm size is 386 employees (with a non reported median of 71) while, by ruling out the projects presented on the Art. 14 (tax credit, i.e., the automatic measure), the average duration of a project is of 2,7 years. As to R&D characteristics of this sample, R&D expenditure is on average 4,95 millions of Euros with a median of 491 thousand Euros (i.e., strong R&D asymmetric distribution with a very long right tail), whereas the average subsidy (calculated with the "gross grant equivalent" method) is about 624 thousands Euros (with median of 234); the ratio of GGE subsidy to the R&D expenditure is 12,5 % on mean and 49,4 % on median. Observe, finally, that the median R&D intensity of the sample is about 3 %, a high level compared to the national aggregated value.

Table 4 shows the differential weight of each single financing instrument. The majority of observations (i.e., "firm per year") receives bottom-up financing (54%); those receiving support from the Law 488 are 14%; top-down project are few, about 4%, while projects with only tax credit ("Only Art. 14") are 24%; firms presenting projects in Objective 1 areas (EU less developed regions) are 20% of the sample, whereas those in collaborative projects are about 13%[5]; finally, projects more oriented to research represent 25%, and those more oriented to development about 14%[6]. In sum, in the period of observation (2000-2004) FAR has been more suitable for bottom-up (valutative procedure) projects than on automatic (non-valutative) or top-down (negotiated procedure) projects.

Table 5 concerns the share of the project cost covered by the public financial support: grants cover, on average, 38 % of the total admitted project costs, while this value reaches a level of 57 % for favorable loans and (only) 34 % for interest discounted contributions. As already indicated in table 1, finally, the total intervention financing covers on average 49 % of the total admitted project's costs, although it reaches a maximum of 86%.

Table 3 presents a simplified outline of the panel_Firb dataset, emphasizing its main features. It refers, for the sake of brevity, just to one firm observed in the considered five years, but it should be seen as a "representative case". The firm has five projects allocated in the following way: three in 2000, one in 2002, one in 2004. Looking at the section "type

[5] This percentage (13%) doesn't represent the amount of the collaborative project within FAR but only in our dataset.

[6] To be "more oriented" means to have more than 75% of the R&D activity devoted to research or to development; the other cases -the majority- represent 61%.

of financing" we observe that in 2000 this firm performs two bottom-up research project and one Law 488 project, while looking at the section "project characteristics" it is easy to see that in 2000 "at least" one of the three project accepted has been a collaborative project, and "at least" one of them more oriented to research (than to development).

Before going on, three important aspects have to be stressed: (1) the dataset includes all the public measures a firm beneficiated from FAR and Law 488 by year, so that the subsidy received by year is a measure of this amount; (2) the evaluation of the additionality is done by comparing the firm's "own R&D expenditure" (that excludes from the total R&D expenditure all the subsidy received by year) in the treated and untreated companies[7]; (3) in one of the next sections, we also tried to evaluate the additionality by single public measure, comparing the differentiated impact of cases with "at least" a single measure ("alone" or within a mix) to that of a mix "without that measure", and the impact of cases with "only a single" measure to that in which that measure is part of a mix of subsidies.

It is of worth to point out that the panel_Firb dataset lacks in information on the presence of R&D subsidy different from FAR and LAW 488, and in particular on the presence of subsidies from FIT or European Framework Programmes. This is due to the lack of an appropriate communication between Miur and Mise as well as between different Departments within Miur.

Our results would not be modified if we could advance the hypothesis that the distribution of FIT (or EUFP) is "uniform" among firms, although it seems more likely that firms which didn't receive any FAR subsidy during the period (2000-2004) received some another type of R&D subsidy (FIT or EUFP) or probably nothing. This "more likely" hypothesis should "reinforce" our results.

Finally it is necessary to present two important assumptions on the subsidy measurement under which our analysis is built:

1. we work under the hypothesis that when a firm's project is accepted for public fund, the firm starts immediately its R&D project (before receiving the public fund), since banks can anticipate the needed resources, if the public acceptance of a firm's projects works as a collateral for the bank, or anyway firms self finance the project[8].

2. as to the approach for calculating the "own R&D expenditure" of each treated firm, as we sketched above, we make use of the GGE (Gross Grant Equivalent) method as recommended by the European Union. When the supporting scheme takes, among other alternatives, the form of favourable credits as well as tax credit, the right way to calculate the proper level of subsidy is the exactly the GGE. This methodology allows for measuring the exact amount of subsidy received according to an actualization formula of the distributed loan's payments along the contracted

[7] In what follows we use the term "treated" and "untreated" firms as synonymous of "supported" and "non-supported" firms.
[8] We work with data on public subsidy commitment and not with subsidy outlays (i.e. effective subsidy allocation), since these last data are not fully available and are less reliable.

years (that in our case is a period of ten years). More details can be found in appendix A.

5 - Variables' description and selected sample

According to the David, Hall and Tool (2000) model (hereafter DHT model) a series of control variables are considered to complete the dataset, in order to perform the econometric evaluation of FAR policy effectiveness. We start with the dependent variable, the firm "own R&D" obtained as the total firm R&D expenditure minus the subsidy (calculated according to the "gross grant equivalent" method and then spread along the project's duration). See appendix A for details. As to the dependent variables table 6 shows both name and definition of each single variable.

Treatment: this is the 0/1 variable indicating whether a given firm is supported or not. This is a common "flag", whose coefficient represent the net effect of the policy as it will be clearer later. In the light of the DHT approach it is (our) "technological policy tool".

Size: apart from accounting for the different economic scale of the firms, it can be seen, according to the DHT model, as a proxy of the "state of demand", since it is strictly collinear with firm turnover.

Knowledge: this variable takes into account the firm past experience in R&D and innovation performance. Moreover, since it is built on capitalized patent expenditures, it approximates quite well the degree of "appropriablity conditions" within the market the firm operates in (the greater the level of this variable, in fact, the greater the need to protect inventions experimented by the firm).

Cash-flow: this is the "self-financing" (or "internal") component within the "corporate financing" structure of the firm (the other are external sources, such as: "leverage" and "equity"). It represents the internal liquidity constraint of the firm and should be seen as the cheaper way to fund investments.

Leverage: debt financing is a key source for firm R&D and non R&D investments. In Italy this is strengthen by the prevalence of SMEs, characterized by a weak propensity to rely on financing via stock markets.

Equity: apart from being the second essential external source of investment financing, this is a proxy of the venture capital availability (as recommended by the DHT model) or, more in general, of the capacity of the firm to find resources outside the internal availability and the bank relationships.

Labor cost: labor intensity seems important in identifying the R&D performance of a firm so that, although not considered in the DHT model, this variable is inserted to take into account differences in the structure of costs.

Capital intensity: as for labor cost, it is a key variable, especially in sector more oriented toward automation or more inclined to yield high-tech products.

Sector: technological opportunities and other technical aspects are without doubt sector-dependent. Including this variable is an essential step to avoid potential biases, due to different firm specializations, and to take into account sampling differences.

Region: regional differences are of worth, especially in countries like Italy, characterized by a uneven economic development along its territory. This variable is important also for taking into account the diverse weight of firms coming from different Italian regions.

Time: according to the DHT model, the last point refers to "macroeconomic conditions". The dummy for time serves as proxy for differences in time along the sample period.

Finally, other four variables are introduced for characterizing projects:

Only Art. 14: it is a 0/1 dummy indicating if the subsidy concerns tax credit or if it does not. Tax credit differentiates itself from other kind of subsidy measures, since it does not follow any evaluation procedure, but it is an "automatic tool", allowing fiscal advantages for the lpast R&D expenditures reported.

Objective 1: it is a dummy 0/1 indicating if the R&D project has been allocated in a Objective 1 area (Mezzogiorno of Italy). This project characteristic seems of some importance and needs to be considered apart as a specific variable.

Collaboration: this dummy assumes value 1 if the firm is engaged in collaborative projects (with other firms or institutions). This variable is of great relevance for the potential internal spillovers and synergies collaborations can produce.

Subsidy allocation: as we said, we are working under the hypothesis that once a firm gets accepted for financing it immediately starts its R&D project, since the bank system provides it with the needed resources on the basis (guarantee) of the public agency commitments, or (more probably) through firm self financing. Nevertheless, during the period some firm can also receive a public funding (mainly from previously accepted projects, not directly related to the current ones) and this occurrence is taken into account in order to achieve fairer conclusions on the effect of the subsidies associated to "current" accepted projects (according to the year considered). This dummy, therefore, assumes value 1 if the firm receive some subsidy allocation in the year considered and 0 otherwise.

Once all these variables are jointly considered for regression analysis, because of the numerous missing values found in the dataset, the number of observations decrease to 4000 while the number of treated units drop to 853 and that of untreated ones to 3147.

6 - The econometric model

The econometric methodology used to evaluate the input (R&D outlay) and output (patents) additionality of FAR is based on the (wider) literature on "program evaluation". The main objective in this literature is estimating the so-called "average treatment effect" on the beneficiaries affected by the policy at stake. A review of this literature, applied to various models for R&D policy, can be found in Cerulli (2009). In what follow we present the logic of the applied model and its estimation counterpart.

As customary within this literature we start from a "selection-into-program" equation to arrive to the estimation of an own R&D expenditure's "reduced form" in a longitudinal (panel) dataset taking into particular account the role played by firm "heterogeneity" in the observable variables. For the use of longitudinal data our reference is the model proposed by Lach (2000), while for the heterogeneity analysis we refer to the model presented in Wooldridge (2002, pp. 608-614).

The starting point is that of modelling three behavioural equations: one for the public agency, aimed at selecting the firms/projects to be financed according to a specific "objective function", one for supported (or treated) firms and one for untreated firms. The public agency behavioural (or "selection") equation takes on the following form:

[1]
$$w^* = \eta + \mathbf{x}_1\boldsymbol{\theta} + a$$
$$w = \begin{cases} 1 & if \quad w^* \geq 0 \\ 0 & if \quad w^* < 0 \end{cases}$$

Where w^* is the optimal level of subsidy conceded by the agency to the firm with characteristics given by the vector of covariates $\mathbf{x_1}$[9], while *w* is the index function (taking zero/one values) denoting the rule according to which the agency decides to finance or not a firm with a certain $\mathbf{x_1}$. The scalar *a*, finally, identifies all the firm/project features that the analyst is unable to observe.

As to the firm behaviour, we have an equations for treated (denoted by the suffix "1") and one for untreated units (denoted by the suffix "0") of this kind:

[2]
$$y_0 = \mu_0 + g_0(\mathbf{x}) + e_0$$
$$y_1 = \mu_1 + g_1(\mathbf{x}) + e_1$$
$$E(e_1) = E(e_0) = 0$$

where *y* is the "own R&D expenditure" (total R&D minus subsidy), *μ* is a constant term, *g(.)* a function (that is assumed to be different in the two groups) of the covariates $\mathbf{x = [x_1; x_1]}$, with $\mathbf{x_2}$[10] denoting firm characteristics affecting the R&D behaviour, other than those affecting the selection behaviour of the agency, and where *e* are unobservable (to analyst) components impacting on R&D and having unconditional zero mean.

According to equations [2] we can get the so-called "benefit from treatment", $(y_1 - y_0)$, as:

[9] The vector $\mathbf{x_1}$ represents the agency "selection" criteria, usually including firm/project characteristics as well as welfare objectives. In our case we include only the first type of variables.
[10] The vector $\mathbf{x_2}$ represents variables referring to the firm R&D choice/strategy and should include the DHT variables of the previous section.

[3] $$y_1 - y_0 = (\mu_1 - \mu_0) + [g_1(\mathbf{x}) - g_0(\mathbf{x})] + (e_1 - e_0)$$

which is a function of three differential terms as it easy to see. In our estimation procedure we are interested in two types of parameters: the so-called “average treatment effect” (ATE) and the “average treatment effect on treated” (ATET) defined, as function of **x**, as:

$$ATE(\mathbf{x}) = E(y_1 - y_0 | \mathbf{x})$$

$$ATET(\mathbf{x}) = E(y_1 - y_0 | \mathbf{x}, w = 1) .$$

The problem in estimating these parameters is that, at the same time, each firm can be observed only in one of the two conditions (if treated or if non-treated) so that, on the side of firm behaviour, a “missing observation” problem arises. To overcome this problem, we need additional hypotheses; we introduce the hypothesis of “conditional mean independence” (CMI) that allows to estimate the parameters of interest through standard OLS. According to the CMI hypothesis we assume that “the unobservable variables affecting the selection into program equation are uncorrelated to the unobservable variables affecting the firm R&D behaviour, once we have conditioned on the observable variables **x**”; technically it means that:

$$a \perp (e_0, e_1) \mid \mathbf{x} ,$$

that, in terms of conditional mean, becomes:

$E(e_0 \mid \mathbf{x}, w) = E(e_0 \mid \mathbf{x}) = 0$ and $E(e_1 \mid \mathbf{x}, x) = E(e_1 \mid \mathbf{x}) = 0$.

It can be shown that, after this hypothesis, the previous parameters become:

$$ATE(\mathbf{x}) = (\mu_1 - \mu_0) + [g_1(\mathbf{x}) - g_0(\mathbf{x})]$$

$$ATET(\mathbf{x}) = E(y_1 - y_0 | \mathrm{w{=}1}) = ATE_{(w=1)}(\mathbf{x}) .$$

To get the *ATE* and *ATET* (unconditional on **x**) we only have to average over the support of **x**, obtaining:

$$ATE = (\mu_1 - \mu_0) + E_{\mathbf{x}}[g_1(\mathbf{x}) - g_0(\mathbf{x})]$$

$$ATET = E_{\mathbf{x}}[ATE_{(w=1)}(\mathbf{x})].$$

The final step is the arrive to a sample estimate of those parameters, that, of course, has to be done in terms of observable variables. To achieve this task we introduce the so-called "switching regression" as:

$$y = wy_1 + (1-w)y_0$$

where y is observable. By replacing y_1 and y_0 with their expression from [2], we get the following relation:

$$y = \mu_0 + g_0(\mathbf{x}) + w(\mu_1 - \mu_0) + w[g_1(\mathbf{x}) - g_0(\mathbf{x})] + u$$

where $u = e_0 + w(e_1 - e_0)$. Moving toward a parametric form of g *by* putting: $g_1(\mathbf{x}) = \eta_1 + \mathbf{x}\boldsymbol{\beta}_1$ and $g_0(\mathbf{x}) = \eta_0 + \mathbf{x}\boldsymbol{\beta}_0$ we can rearrange the previous equation getting, after simple manipulations, the following "reduced form" regression equation:

[5] $$E(y \mid \mathbf{x}, w) = \gamma + \mathbf{x}\boldsymbol{\beta}_0 + w \cdot \alpha + w \cdot [\mathbf{x} - \boldsymbol{\mu}_{\mathbf{x}}]\boldsymbol{\delta}$$

where it can be proved that $\gamma = \mu_0 + \eta_0$, $\alpha = ATE$, $\boldsymbol{\delta} = (\boldsymbol{\beta}_1 - \boldsymbol{\beta}_0)$ and $\boldsymbol{\mu}_{\mathbf{x}} = \mathbf{E(x)}$. Equation [5] can be estimated consistently by OLS, and once obtained the OLS parameters we can get the various treatment effects by simple transformations of the type:

[6]
$$\hat{ATE} = \hat{\alpha}$$
$$\hat{ATE}(\mathbf{x}) = \hat{\alpha} + (\mathbf{x} - \overline{\mathbf{x}})\hat{\boldsymbol{\delta}}$$
$$\hat{ATET} = \hat{\alpha} + (1/N^T)\sum_{i=1}^{N} w(\mathbf{x} - \overline{\mathbf{x}})\hat{\boldsymbol{\delta}}$$
$$\hat{ATET}(\mathbf{x}) = \left[\hat{\alpha} + (\mathbf{x} - \overline{\mathbf{x}})\hat{\boldsymbol{\delta}}\right]_{(w=1)}.$$

Relations [6] are all estimable since they are function of observable (to analyst) components. The only difficulty is that of obtaining standard errors for the *ATET*, a problem that can be overcome by bootstrapping.

As to the form of our “control group” it is important to stress that it is represented by a group of firm/year that: (1) did not apply for subsidies at all, (2) applied for subsidies but was refused, i.e., did not receive any public funding commitment for their project application during the period (2000-2004). Observe in any case that, as projects generally last more than one year, a given firm getting a project accepted in one year becomes treated also for the next year just according to its project time span; it means that the number of treated observations (again, firm/year) increases after our public fund’s spreading procedure, reducing the number of untreated observations accordingly.

The firms of the control group are all recorded in the “Anagrafe della ricerca”, in so showing a certain willingness/propensity to apply for FAR /Law 488 subsidy policy (that is, a certain homogeneity with treated units). Moreover, in our sample treated and untreated firms have very similar structural characteristics, except for *Size* and *Knowledge*. Nevertheless, since we use a linear multiple regression we do not need to generate a “similar-to-treated” control group as required, for instance, by *Matching* approaches: in our case it is sufficient to insert (in particular) those covariates controlling for firms differences as we did for the *Size* and *Knowledge* in our application. However, in the output additionality exercise (that on the effect of subsidies on the number of filed patents), we will make use of a *Matching* model because more suitable in that context of analysis.

In what follows we present results by estimating the parameters of [6]. We only want to stress that in the firms’ subgroup analysis we will work under the additional hypothesis that $g_1(\mathbf{x}) = g_0(\mathbf{x})$, that makes *ATE* = *ATET* simplifying significantly the analysis.

7 - Results

According to the model proposed above this section presents the main results on “input additionality”, that is on the capacity of firms to “top up” an addition R&D expenditure to their observed R&D performance, net of the subsidy component (i.e. what firm should do in absence of the subsidy). On average, the additionality occurs when the value of the parameter α is positive and statistically significant. Nevertheless the possibility of estimating *ATE*(**x**) as well as *ATET*(**x**) does shed more light on the distributional characteristics of the single parameters *ATE* and *ATET*, in so providing idiosyncratic firm-specific treatment effect; indeed, going beyond an aggregated average value, seems of a great importance for a more in-depth understanding of the policy effect under study. The report of results are organized as follows:

- first, we provide results for the pooled regression for detecting, at an aggregated level, if there exists a "crowding-out" or an "additionality" effect on firm own R&D investment. Here we work under the hypothesis that $g_1(\mathbf{x}) = g_0(\mathbf{x}) = g(\mathbf{x})$, so that the parameter α estimates both the *ATE* and *ATET*.

- second, we allow for $g_1(\mathbf{x}) \neq g_0(\mathbf{x})$ so that α =*ATE* ≠ *ATET*; then we fix our attention on the estimation of the distribution of *ATET*(**x**) showing its graphical representation and the main characteristics of its distribution. As we said, this is a firm-specific measure of the causal effect of FAR on firm R&D performance;

- third, we go beyond the aggregate result by splitting our sample according to different and heterogeneous firm characteristics. In particular we estimate regression [5] in subsets of firms by size, Italian macro-regions, type of technology and by the share of the project costs covered by the subsidy; finally, an analysis of the mix of instrument is also provided: here we are interested in seeing if a different portfolio of subsidy generate differential effects;

- fourth, we provide evidence upon the differences in term of economic and structural characteristics between the group of firm performing additionality and those performing crowding-out. These step is drawn upon the results of the second step. Here what matters is to identify the leading factors characterizing the policy's success and possibly their relations with the agency's selection criteria.

Input additionality: overall sample

Table 8 considers results from the aggregated sample under the $g_1(\mathbf{x}) = g_0(\mathbf{x})$ hypothesis. Column 1 shows the effect of the treatment dummy on the own R&D expenditure without covariates (simple t-test comparison between the two group), while column 2 and 3 introduce some cleaning of the data.

The most important regression, which we labelled the "fundamental" one, is in column 4, where a series of covariates has been introduced: it shows a positive and significant average treatment effect on treated (*ATET*) of FAR on firm own R&D expenditure of about 801 thousand Euros: it means that this additionality (that can be seen as the "own R&D of treated" minus the "own R&D of untreated" units) is of about 40% of the untreated firms' R&D average[11].

The *Size* is also positive and strongly significant, with an increase of about 4 thousand Euros of own R&D expenditure per one additional employee; also the presence of collaborative project (*Collaboration*) marks a positive and highly significant effect (about

[11] More in detail, the average own R&D expenditure of the untreated units is about 570 thousand Euros. Indeed: (801-570)/570 ≈ 0.40.

9,8 millions of Euros), as well as the presence of a subsidy allocation from the agency (with a value of 3,3 millions of Euros). Observe the negative significance of the automatic policy instrument[12] (Art. 14, i.e., tax credit) showing the presence of a strong crowding-out (about -2,3 millions of Euros).

Apart from the *Leverage* (just very slightly positive and significant) the other financing variables (*Cash-flow* and *Equity*) are not significant, although with a positive sign, in explaining the firm own R&D performance. Cost variables are not significant too. It seems, in other words, that the liquidity constraints as well as the ability to find external source of financing are not distinguishing factors in explaining the additionality's capacity of the firm. As it will be more understandable later, this aspect deserves further attention.

Estimation and distributional features of ATE(**x**) *and* ATET(**x**)

According to the estimation of equation [5] and to formulas [6], it is possible to calculate the firm-specific ATE(**x**) and ATET(**x**), with their distributional characteristics. In this section we are working under the hypothesis that $g_1(\mathbf{x}) \neq g_0(\mathbf{x})$.

Figure 1 shows the graphical representation of the ATE(**x**) and ATET(**x**) for FAR in the overall sample, while the descriptive characteristics of the ATET(**x**) distribution are set out in the Table 9.

Table 9, as well as figure 1, emphasizes one of the most important results of our research: the median of the ATET(**x**) is about zero. It means that half of our sample perform a crowding-out, whereas the second half an additionality result. What is interesting too, is that the ATET(**x**) mean is positive (and significant), but only because of the existence of a strong right asymmetry of the ATET(**x**) distribution, with positive values significantly higher than negative value in absolute terms. This is a surprising, as well as a very characterizing aspect of FAR, that only the knowledge of the entire distribution of the effect can put into evidence. Observe that the mean of the ATET(**x**) in table 9 is about 878 thousand Euros, that is slightly different from the value of 801 obtained in table 8: this is due, as we said, to the hypothesis that $g_1(\mathbf{x}) \neq g_0(\mathbf{x})$ of the ATET(**x**) model. Nevertheless this difference is largely negligible and in the rest of the paper we will work under the assumption that $g_1(\mathbf{x}) = g_0(\mathbf{x})$.

8 - The analysis by subsets of firms

So far we have considered results from an aggregated perspective. Nevertheless firms are in their essence strongly heterogeneous and we expect to find differences in FAR effect according to different subgroups of firms. In particular we are interested in shedding some

[12] Since the benefit from "tax credit" is calculated on past R&D activities we have checked the presence of additionality/crowding-out for this fiscal measure also by allowing for one and two time lags of the own R&D expenditure, getting in any case the same negative result as in the contemporaneous case of Table 8 (a table on these last estimates have not been reported).

light on the size, sectoral specialization, geographical origin and degree of financial support for these firms. The next sections show the results.

Additionality by size

From table 10 it is immediate to see that only for large (and very large) firms there is a significant positive additionality (about 1.148 and 2.273 thousand Euros respectively). SME's effect is neutral (neither crouding-out, nor additionality), while small firms present a negative sign (-174), even if not significant.

The *Size*, as in the pooled sample, is always positive and significant, but its magnitude lowers passing from small to very large firms. *Knowledge*, as expected, is positive and significant only for large and very large firms, since they rely more on patenting activity than SMEs. The dummy "Only Art. 14" (tax credit) is negative and significant for SMEs, while it is dropped for large firms (since this automatic instrument refers only to small sized enterprises). The variable *Collaboration* (presence of R&D project collaborations) and *Objective 1* (depressed areas) are positive and significant only for large and very large firms. The variable *Collaboration* for SMEs is not significant: the estimator has a large range of variation. There are, among other things, differences between small firms (with a positive sign) and medium firms (with a negative sign)[13].

The *Leverage* is (slightly) positive and significant only for medium sized enterprises (50-100 employees), while the *Cash-flow* has a negative and significant effect only for large and very large firms; notice, however the positive and significant (but only at 10%) coefficient of *Equity* for large firms: it seems that larger firms prefer to use external rather than internal sources to finance their R&D projects, while SMEs seem prefer internal sources (indeed, for medium sized enterprises the *Cash-flaw* is positive and quite significant).

Additionality by sectoral specialization in manufacturing

Quite surprisingly table 11 shows a positive and significant effect of FAR on manufacturing low-tech firms (about 868 thousand Euros), although high and medium tech present positive values too (with a value for high-techs that is twice that of medium-techs). The size of these low-techs is in any case quite high, about 320 employees, although they are few when compared with the number of observations of the other types of firms (we are left with only 317 low-techs). Furthermore, the level of additionality of these low-techs firms is very close to that got by the full sample. As expected, the variable *Knowledge* is highly positive and significant for high-tech manufacturing firms and only positive (but not significant) for medium and low-techs. The *Size* continues to be an important factor in explaining own R&D performance for all types of firms, while tax credit (*Only Art. 14*) produces a significant crowding-out only for high-techs.

[13] Probably the results are due to two factors: first, not all the collaborative projects are included in our dataset (which is the result of a merging between three different starting datasets), and second the collaborative projects include top-down programmes in which mainly large firms participate.

Additionality by Italian macro-regions

Table 12 shows that the effect (always the ATET) is positive and significant in the North and Center of Italy, with a value of about 735 (North) and 1.600 (Center) thousand Euros respectively. For the South the ATET is not significant and also negative in its level. Nevertheless, it seems of worth to observe that the number of observations is not equally distributed: the North has the greater number of about 3.000 while the South just 242. Observe again the joint significance of *Size*, *Collaboration*, *Objective 1* and *Subsidy allocation* for all three regressions. Finally, *Only Art. 14* remains negative and significant as in the pooled regression.

Additionality according to different financing intensity

Table 13 shows regression comparison according to three percentile classes of the "financing intensity" (defined as the subsidy share of the total project cost): *w1*, *w2* and *w3* are treatment dummy variables for low, medium and highly financed firms respectively.

We can observe that, as soon as we move towards more intensively financed firms, the table sets out that the level of the effect increases: from about 500 thousand Euros of additionality in the first and second class, to 1.890 in the third one; furthermore, only for the third percentile class the effect is really significant. This results puts into evidence that the positive effect of the subsidy starts only above a certain threshold, that in this application is a financing of about 50 % of the total cost.

9 - Impact by instrument and mix of instruments

For the analysis of the effect of single instruments as well as of their mix, we start by defining a dummy for each instrument:

D1= bottom-up Law 297 (Art. 5 and 6). They are 1.410 total cases, of which 1.204 alone.

D2= top-down measures (Art. 11 and 12). They are 140 cases, of which 79 alone.

D3 = bottom-up Law 488. They are 413 cases, of which 312 alone.

D4= other instruments.

What do these dummies compare? According to their definition, for each instrument they compare two groups of firms: the first one is that in which the instrument was used by a firm with or without other instruments and the second on is that in which the measure[14] is not present, i.e., only other instruments are included or firms receive no subsidy. In this way we obtain the additionality effect by single instrument, and we can compare the

[14] We use the words "instrument" or "measure" interchangeably.

effects among different measures. Moreover, we tested the additionality effect of different mix of instruments (for instance: *D1* x *D2*) with their complement.

Table 14 shows these effects for single policy instruments as well as for some of their combinations. As it is easy to see bottom-up projects (*D1* for Law 297 and *D3* for Law 488) provide significant additionality in line with the average value (pooled regression of table 8). Top-down projects, on the contrary, show a negative and significant effect: nevertheless, this last result hinges on only 35 observations[15], so it has to be taken with caution.

When bottom-up projects are joint together, their strength increases considerably (see the coefficient of *D1D3*). The other results do not deserve further comments, since the number of observations it too low to draw reliable conclusions.

In order to deepen the analysis on the mix of instruments we also performed single regressions using a new dummy for each instrument, built in the following way: we compared two groups of firms, those exploiting the single instruments (without any other measure) and those using the same instrument joined with other measures. We got results (table not reported) only for bottom-up instruments (Law 297 and Law 488) because of few observations. We found that the difference is positive in the case of joined instruments for both measures, but statistically significant only for the Law 488. In particular we got a coefficient of 2.643 thousand Euros with a p-value of 0,155 for bottom-up measures of Law 297 (with 552 observations) and a coefficient of 7.447 thousand Euros with a p-value of 0,039 for bottom-up measures of Law 488 (with 167 observations).

10 - Structural differences between the “crowding-out” and the “additionality” group

Which are the distinguishing characteristics of the group of firms performing crowding-out compared with those performing additionality? Answering this question seems important, both analytically, because it allows to go beyond the aggregate result on the ATET, and normatively, since it appears to be an important information for policy makers.

We saw that half of the supported unit do an additionality, while the other half do an crowding-out result. This means that we can establish a clear-cut threshold, the median of the ATET distribution, tracing out quite clearly the composite effect of the policy at stake.

Operatively, we form two groups, the “crowding-out” and the “additionality” group, according to the (zero) median of the ATET(**x**), and we try to characterize them by comparing a wide set of variables-characteristics in order to shed more light on which are the essential (structural) differences among these two groups. We point to answer this question: which factors make a firm more able to exploit in an additional way the support received?

[15] The introduction of covariates reduces the number of observations because of the numerous missing values.

The literature suggests to look at three groups of variables, according to three theoretical perspectives we take into account: “industrial organization”, “corporate financing” and “innovative capacity” variables. Results on these three set of variables are visible in table 15.A and table 15.B.

By looking at the mean and, more correctly (since many variables are strongly asymmetric with a long right tail) at the median of the distribution of these variables, we can observe some important aspects:

The *Size*, in terms of number of employees, is an harsh demarcation factor: the group of firms performing additionality is, on average, more than 10 times larger than the group of firm doing crowding-out. In terms of median, since we deal with very large right tails, this value becomes about 6 times, a still high value.

In terms of *Turnover*, both the mean and median of the additionality group is largely higher than that of the crowding-out group. It confirms the result on *Size*, with the additionality group performing a median turnover about 10 times greater than that of the crowding-out group.

What is surprising is that, in terms of R&D per employee, i.e. in terms of “firm input capacity” (or R&D competence) in an innovation function, the two groups reach a very similar result: quite unexpectedly, the “crowding-out” group performs in median 6.5 thousand Euros of R&D per employee compared with a value of 5.2 of the additionality group. R&D intensity capacity doesn’t seem hence an essential factor for explaining the ability of performing additional R&D expenditure, once received a proper support[16].

For the sake of brevity, by looking at all the corporate financing variables (*Cash-flow*, *Leverage*, *Equity*, etc.) we can observe a general similarity in the two group. It seems that, from a financial point of view they are quite indistinguishable, so that no differential financial constrains are able to justify different additionality performance (we only observe a little higher level of *Cash-flow* availability in the additionality group).

The *Operating profit margin* (*OPM*, a proxy of the firm relative market power) does not seem to matter as well. We cannot invoke, at least at this stage, the idea that the additionality group includes firms with a greater market power compared to the “crowding-out” group.

The share of R&D project costs covered by FAR support is the same in the two group showing that also this element does not participate in explaining potentially differential advantages of one group over the other.

Also in terms of *Sector* the two groups do not present appreciable differences: in the crowding-out group the first two sectors (in terms of number of observations) are the machinery industry (22%) and chemicals/pharmaceuticals (12%), as well as in the additionality group where the machinery industry is the first one (18%) followed by chemicals/pharmaceuticals (15%).

[16] Of course, since we are looking at firms generally having an R&D activity, the lower the firms size (as in the case of the “crowding-out” group) the higher their R&D intensity.

The *Region* too does not mark differences: Lombardia, Emilia Romagna, Veneto and Piemonte are the main regions in which firms are located and follow in the same order in both the samples.

Finally, as to the "delay between the project application and final positive acceptance" no differences arise: both samples present an average of about 22 months and the form of the distribution of this variables is also very similar in the two groups.

The most important difference, apart from the size, refers to the "propensity to patent". The average number of patents applications of the additionality group is about 6 times that of the crowding-out group (and 3 times in terms of median). The median investment rate of the additionality group is not particularly different from that of the crowding-out group and is in both cases negative.

What can we conclude from this analysis? Very concisely, we can state that financial constraints do not seems able to qualify a different "propensity" to perform additionality. Indeed, while financial variables affect the public agency selection, they do not appear able to disentangle differences within the group of treated units (either if they do additionality or crowding-out). This is a first important point.

The size is an essential demarcation factor. Larger firms tend to perform additionality more easily than smaller firms and this aspect deserves further inspection.

A central point is that, while the two groups present a similar R&D intensity, they have very different performances in terms of patenting activity. This requires some further discussion. In fact, what seems to emerge is a greater ability of the "additionality" group in transforming their inventive inputs (mainly, the R&D intensity) in innovative outputs (in our case, the number of patent applications): this identifies a different "innovation production function" in the two groups. This clearly can rely on two essential ingredients: "scale economies" (linked essentially to the firm size) and "strategies" (firm choices and objectives). As to the first element a well known literature (starting from the Schumpeter Mark II paradigm of the innovation process) points out the benefits (increasing return to scale) deriving from a higher size: wider and better internal division of labour (benefits from specialization), greater capacity of internalizing/exploiting network and knowledge (R&D linked) spillovers, greater facility to reach and contact new markets, greater market and non-market (political) power, and so on. As to the second element ("strategies"), it seems possible to observe a greater propensity to grow up in the additionality group rather than in the crowding-out one. It could be quite puzzling since the second group starts from a very lower size. Probably this mirrors the specific Italian system of innovation, where SMEs (the great majority of firms) seem to be historically more projected towards short-term returns (profits) than long-term objectives, such as the growth. Many previous researchers, indeed, have emphasized how Italian SMEs are reluctant to strategies pointed at enlarging the scale of production (through, for example, an active financing on stock markets), in so remaining, essentially, under-capitalized. This is due, among other things, to the Italian traditional familiar ownership of the firm and on its connected "fear" to lose power and strategic control.

In conclusion, a different innovation function (stimulated by a different average size) and the scope of the strategies pursued, seems to affect the occurring of a crowding-out rather than an additionality behaviour more than the industrial structure (market power), corporate financing components (leverage, equity, cash-flow), or a strict knowledge input capacity (R&D intensity).

11 - The analysis of the "output additionality": the effect on firm patenting

The forgone analysis focused on the "input additionality", i.e. on measuring the effect of FAR on the target variable, the firm "own R&D expenditure". If the main objective of FAR is that of enlarging the R&D performance of Italian firms, own R&D is the proper variable to look at.

Nevertheless, as suggested by many authors, the enlargement of firms' R&D expenditure should be seen only as an intermediary step. Indeed, the public agency, in implementing its technological policy, should be interested in enhancing the firms' innovativeness, where an increase in R&D is an essential precondition. In the innovation production function, indeed, the R&D activity is the main ingredient (the "input"), but nothing assures that an increase in R&D will be automatically translated into an increase in the firm innovative performance; neither in the third and final step of this chain, the firm economic profitability deriving to the innovation performance. Figure 2 tries to enlighten this chain: FAR policy is on the upstream point of the link between R&D and economic performance, that is the downstream point. In each of these three steps different elements participate in strengthening or weakening the links.

In this section we pay attention to the second link of figure 2, regarding the effect of FAR on firms' innovativeness, measured in terms of "number of filed patents", *via the effect of FAR on R&D performance*. This last sentence deserves further explanation. Indeed, it seems incorrect to study in a "direct" manner the effect of a an R&D policy on technological output (patents, for example), without in other words passing through the pre-existing effect on R&D. More precisely, adopting a "two steps" approach (from policy to R&D, from R&D to innovation) seems to be a more reliable procedure than a "one step" method (from policy to innovativeness). Many authors adopted the one step pattern, but we prefer the two steps, since what we need, in order to judge the effectiveness of a policy on innovativeness, is its ability in fostering innovation *via* its capacity in fostering R&D additionality. In other words, we are interested in measuring the effect of the "additionality" brought about by FAR on firm innovativeness, or, put differently, the effect of the incremental R&D activated by FAR on patents. At this stage, however, we do not go into the direction of analyzing the third and final step (from innovativeness to economic performance).

Operatively, we have to translate this reasoning into a model able to catch the link between FAR and R&D additionality, and that between R&D additionality and innovativeness. The idea is to apply the following procedure, based on the "Matching approach":

Step 1.

By a Nearest Neighbour Matching (NNM) obtain the "own R&D expenditure" of the firm *i*-th's non-supported nearest neighbour. Accordingly, take this value as "the level of R&D the firm would have done without any public intervention".

Step 2.

Split the "total R&D expenditure" of the firm *i* into its three components: (1) the NN-own R&D of step 1, (2) the level of the subsidy received by the firm *i*, (3) the level of the idiosyncratic "additionality" performed by the firm *i*.

Step 3.

Calculate a Poisson regression of the "number of patents" on those three components plus covariates, "only" on the sample of supported firms. If the "additionality" component generate positive and significant results we can conclude that an effect of FAR on innovativeness does exist.

According to the Step 1, we implement the NNM whose results on the goodness of the performed matching can be seen in figure 3. Here we can observe that the distribution of the "propensity scores" after the NNM in the supported and non-supported firms are very similar compared to the pre-matching situation in which they appeared very dissimilar: it indicates that the we can trust our matching approach.

After Step 1 and according to Step 2, then, we can calculate the "own R&D expenditure" of the firm *i*-th's non-supported nearest neighbour that we indicate as ${}^{NN(i)}R_j^C$, as well the level of additionality for the firm *i*, α_i, obtained as the difference between the own R&D of firm *i* and ${}^{NN(i)}R_j^C$. We finally indicate with S_i the level of the subsisy obtained by the firm *i*-th.

Finally, we implement Step 3 by splitting (only for the supported firms, of course) the "total R&D expenditure" (R_i) into its three "potential components" (${}^{NN(i)}R_j^C,\ S_i,\ \alpha_i$), applying a standard Poisson regression of the type:

$$PAT_i = f\,({}^{NN(i)}R_j^C,\ S_i,\ \alpha_i,\ \mathbf{x})$$

where PAT_i is the number of patents filed by the firm *i* and x a set of covariates[17]. As we said, we are particularly interested on the effect of α_i.

[17] Since the NNM already makes use of the covariates used in the regression analysis, in the Poisson regression we only use as covariates: *Region*, *Sector*, *Time* and *Size*.

Table 16 shows the results of this Poisson regression. The estimation of the parameters are semi-elasticities. As it is immediate to notice, the variable *Additionality* (α_i) is significant and positive with a value of 0,035: it means that, on average, if the additionality increases of 1 million of Euros (this is our scale), then the patenting activity increase of 3,5%. This value for medium and low tech firms reach a level of about 8% and 30% respectively. Privately financed R&D is significant and positive only for low-techs (with a semi-elasticity of 0,27) and the level of the subsidy only for medium (with a level of 1,7).

This result strengthens the conclusion we have reached on input additionality (own R&D investment): also on the side of the capacity of activating firm innovativeness FAR seems to have been effective. This is the conclusion reached by our "two steps" procedure. Nevertheless, the reduced number of observations do not allow us to look inside this aggregated result (as we did in the case of input additionality). A result, however, deserves more attention: both in terms of increased R&D expenditure and in terms of growth in the number of filed patents, FAR seems to have been particularly successful for low-tech firms. They are, however, low-techs of large size probably trying to perform a technological shift from more traditional to more sophisticated products and process although belonging to very traditional sectors; at the same time they can be probably seen as the "high-tech of the low-tech", that is, those firms working on the technological frontier of their sectors. In any case, the idea that FAR has been able to increase the technological underpinnings of these kind of firms seem to be an additional proof of its success in terms of ability to promote innovation exactly where new technologies are generally less widespread.

12 - Some results on firm economic performance

Our last analysis points to measure the impact of Far on some economic performance indicators. We consider the following three indicators: the labour productivity (measured simply as the ratio of the turnover to the number of employees), the profitability (as operating profit margin) and growth (as turnover's rate of growth). We calculate these indicators in the crowding-out and additionality group along the period examined by this exercise (2000-2004). This is not a post-treatment analysis, as we do not have information on accounting variables after 2004, but we believe it to be anyway a useful exercise to describe the temporal pattern of the Far effect.

Figure 4 sets out the results. It is easy to observe that productivity and profitability follow a very similar path. Indeed, the additionality group gets: a better performance in the first two years (2000 and 2001), a result very similar to the crowding-out group in 2002, a disadvantage in 2003, and again an outcome similar to the crowding-out in 2004. Overall, the figure seems to show quite clearly a lack of a uniform "dominance" of the additionality group. Indeed, what seems to emerge is that its starting advantage in 2000 reduces during the period considered until no difference in the two groups arises. How can we account for this puzzling pattern? Along with this econometric analysis, the FIRB project has also realized a survey on 3400 firms receiving at least one public R&D and innovation support in 1998-2007. The results from this survey - conducted by the Confidustria (the Italian association of entrepreneurs) - can help to explain quite well the previous pattern. In fact, what emerges from this survey is that the 93% of firms cover their R&D project's costs by self-financing, more than 60% use public funds and only 25% exclusively self-financing. Nevertheless, problems coming from time delays in funds' provision and from uncertainty in the actual availability of public money, generate (further) firm financial constraints. Indeed, firms end up by use self-financing to cover in advance accepted project's costs and more than 70% of them declare to suffer of heavy liquidity problems because of that. This phenomenon is particularly constraining for firms deciding to add incremental projects to those allowed by the public incentive (that is, for companies doing additionality). In this sense the pattern of productivity and profitability is legible according to this perspective. Of course, as our dataset is unable to see after 2004, inferring about the post-treatment long-run effects of the subsidy is not possible. In this sense, we cannot explore if a recovery of the additionality group will occur, once the beneficial market returns from the additional innovative projects will appear.

In terms of economic growth, finally, the median shows no particular differences in the two groups, although the results on the mean seem to set out a better performance of the crowding-out group. Given the high skewness of this variable, however, we prefer to rely on results on the median rather than on those on the mean.

13 - Conclusion

According to the results provided by our model, FAR seems to have been successful both in terms of its capacity to promote "input additionality" (own R&D performance) and "output additionality" (patenting performance): we got a 40% of R&D additionality for the average firm (about 800 thousand Euros of additional "own R&D investment"), and a 3.5% increase in the number of patents for any 1 million of "additional" firm own R&D expenditure.

Nevertheless substantial differences concern various subsets of firms. As to the two groups of firms performing additionality and doing crowding-out, we observe that firms doing additionality are generally larger, more oriented to patent, more prompt to enlarge their fixed capital stock, but similar to the crowding-out group for R&D intensity, structure of costs and corporate financing variables. How can we explain this findings? In the paper we embrace an explanation based on the role played by "scale economies" on one hand and "strategies" on the other:

- larger firms exploit higher "scale economies" through greater internal division of labour (specialization), access to wider internal and external networks, ability in generating and absorbing spillovers, market/political power, easier access to credit and equity etc.;

- different "strategies" seem to be at work, as larger firm appear more "forward looking" at long-term objective. Italian SMEs, on the contrary, seem to be historically more projected towards short-term returns (immediate profits). This is due, among other things, to the Italian traditional "familiar ownership" of the firm and on its connected "fear" to lose power and strategic control.

Having found such features of the "additionality" group pushes us to rethinking about the selection criteria adopted by the agency in order to make policy interventions more profitable in the field of R&D and innovation. Indeed, finding that corporate financing variables as well as the structure of costs (in other words, the idiosyncratic firm financial risk) do not account for performing additionality or crowding-out, should not be surprising: these are the basic criteria the agency actually uses for selecting "good" firms/projects and indeed both the two groups were successful in being selected for funding. What makes the difference relies on other aspects that are more tied to firm behaviours/choices/objectives, as well as to their size of course.

To be more successful the R&D policies should pay more attention to these aspects. For a given level of size, the message seems to state that: "strategies" really matter. Doing R&D without long-run plans in terms of growth, networking, alliances and/or mergers in an even more competitive and the globalized market seems to be a non-sustainable strategy. The public agency's selection procedure should incorporate this message by providing additional requirements other than the classical balance sheet indicators and project quality: these requirements are, of course, less tangible than the traditional ones, since they are embedded in the firm "vision" of itself, of the environment it operates in (competitors, imitators, innovation leaders), of the evolution of markets and technologies. All issues that are sometimes culturally determined and conditioned by socio-political mechanisms, as well as by the economic/territorial atmosphere (more based on competition than cooperation, for example) the firm is grounded in. Some of the strategic orientation can be found in the firm medium term plan and the reform of FAR has gone in the right direction, when it has included two new pre-conditions for the selection of large projects: firms have to demonstrate the additionality character of the demanded subsidy and have to include a three year R&D plan.

In sum, FAR seems an instrument more suitable for large firms: in this case it can operate with largely positive results, while SMEs need more specific and probably targeted (not bottom-up) instruments. Large firms are also the natural candidates for top-down programmes, but at the present state of knowledge it is difficult to say if a satisfactory additionality results also from that type of policy intervention.

Beyond input and output additionality, of course, other type of effects need to be checked, concerning changes in firm behaviour, such as anticipation of future projects or change in the content of projects, as well as change in the R&D localization, but this analysis can be better developed through surveys.

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Annex 1 – Tables and figures

TABLE 1. Main features of the "panel_firb" dataset. Note: with the term "subsidy" we intend the level of the public financing according to the "gross grant equivalent" method.

Name	Panel_firb
Unit of observation	Firm per year
Time span	2000-2004
N. of years	5
N. of firms	2321
N. of observations	11605
N. of supported firms	1845 (1200)
N. of non-supported firms	9760 (10405)
Average firm size	386 employees
Method for the calculus of the subsidy	GGE (Gross Grant Equivalent)
Average financing share on costs' project	0.49
Average project duration	2.7 years
N. of obs. with only one project in the period	56%
Firms located in the North of Italy	65%
A. Average R&D expenditure per year	4,95 million of Euros
B. Median R&D expenditure per year	491 thousand Euros
C. Maximum R&D expenditure per year	467 millions of Euros
D. Average subsidy per year	624 thousand Euros
E. Median subsidy per year	234 thousand Euros
F. Maximum subsidy per year	38,2 millions of Euros
D / A in percentage (mean)	12.5 %
E / B in percentage (median)	49.4 %
F / C in percentage (maximum)	8.1 %
Average Turnover	40.7 billions of Euros
Median Turnover	16 million of Euros
Median R&D intensity	3.06 %

TABLE 2. Number of supported and non-supported firms in the "panel_Firb_c" and "panel_Firb" dataset.

Dataset	**Panel_Firb_c**	**Panel_Firb**	**Panel_Firb after subsidy redistribution**
	N. of firms	N. of firms per year	N. of firms per year
Supported	900	1200	1845
whose:			
Only ART. 14	223	346	575
other	677	854	1270

TABLE 3. Schematic structure of the longitudinal dataset used in the analysis.

				TYPE OF FINANCING							PROJECT CHARACTERISTICS					
ID	YEAR	N. OF PROJECT IN THE PERIOD	N. OF PROJECT IN THE YEAR	BOTTOM-UP RESEARCH	BOTTOM-UP TRAINING	TOP-DOWN	LAW 488	TAX CREDIT ART.14	ONLY ART.14	OTHER	COLLABORATION	OB1	RES	DEV	RES-DEV	MAX DURATION (2000-2004)
1	2000	5	3	2			1				1	0	1			36
1	2001	5														
1	2002	5	1			1					0			1		12
1	2003	5														
1	2004	5	1	1							0				1	24

TABLE 4. Weight of single instruments in the "panel_Firb" dataset.

Instrument	**Freq.**	**%**
Only ART.14	346	28.83
At least one bottom-up research project	649	54.08
At least one bottom-up training project	13	1.08
At least Law 488 project	166	13.83
At least one top-down research project	47	3.92
At least one Art.14 research project	83	6.92
At least one "other" research project	13	1.08
At least one collaborative research project	153	12.75
At least one OB1 research project	229	19.08
Research and Development	**Freq.**	**%**
Research	199	25.42
Research and development	475	60.66
Development	109	13.92
Total	783	100

TABLE 5. Weight of the type of public financing on projects costs.

Obs	**Mean**	**Std.Dev.**	**Min**	**Max**
"Admitted cost" on "total cost"				
619	.974	.117	.046	1
"Total financing" on "Admitted cost"				
619	.490	.139	.008	.861
"Grant" on "Admitted cost"				
618	.386	.190	.002	.813
"Favorable loans" on "Admitted cost"				
385	.576	.115	.113	.750
"Interest discount" on "Admitted cost"				
38	.341	.122	.082	.550

TABLE 6. Dependent and independent variables' description.

DEPENDENT VARIABLE	
Own R&D	= total R/S expenditure – subsidy
COVARIATES	
Treatment (t)	0/1 dummy at time t
Knowledge	Stock of capitalized expenditures for patents to total turnover
Leverage	Debt to turnover
Cash-flow	Non-distributed profit sto turnover
Equity	Owners' Equity to turnover
Labour-cost	Labour costs to turnover
Capital Intensity	Stock of equipments to turnover
Size	Number of employees
Only Art.14	dummy: 1 = observation with only an ART. 14 project
Objective 1	dummy: 1 = obs. with at least one project in area Ob1
Collaboration	dummy: 1 = obs. with at least one collaborative project
Subsidy allocation	dummy: 1 = presence of some support supply
Sector	dummy: sector NACE 2-digit
Region	dummy: regional localization of the firm
Year	dummy: year (2000-2004)

TABLE 7. Characteristics of the sample used in the regression analysis.

Number of obs.	4000
Number of treated	853
Number of untreated	3147
Average size	366 Size
Prevailing sectors (2)	29 (mechanics), 24 (Chemicals and pharmaceuticals)
Prevailing regions (2)	Lombardia, Emilia Romagna
Prevailing year of treatment	2002

TABLE 8. Average treatment effect on treated (ATET): OLS in the pooled sample; results on sectoral, regional and time dummies omitted; standard errors in parentheses; * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Values are thousand Euros.

Dep. Var.: Firm own R&D expenditure	(1) T-TEST (total sample)	(2) T-TEST (total sample + no supply)	(3) T-TEST (no supply + cleaning)	(4) REG-F (fundamental regression)
Treatment(t)	4300.45***	3676.47***	579.72***	801.13***
	(969.69)	(939.71)	(157.70)	(291.91)
Knowledge				514.87
				(518.92)
Leverage				64.28*
				(36.22)
Cash-flow				113.46
				(216.48)
Equity				15.65
				(78.27)
Labour-cost				-238.94
				(424.13)
Capital Intensity				216.89**
				(89.44)
Size				4.18***
				(0.40)
Only Art.14				-2280.78***
				(502.76)
Objective 1				2306.74*
				(1227.07)
Collaboration				9812.97***
				(2402.34)
Subsidy allocation				3264.48***
				(1136.20)
N	5971	5793	5690	4000
N. of treated	1159	985	942	853
adj. R^2	0.007	0.006	0.002	0.387
r2	0.01	0.01	0.00	0.40
F	19.67	15.31	13.51	14.36
ll	-67488.79	-65024.62	-55505.88	-40140.13

FIGURE 1. Comparison between the distribution of ATE(**x**) and ATET(**x**) in the regression sample.

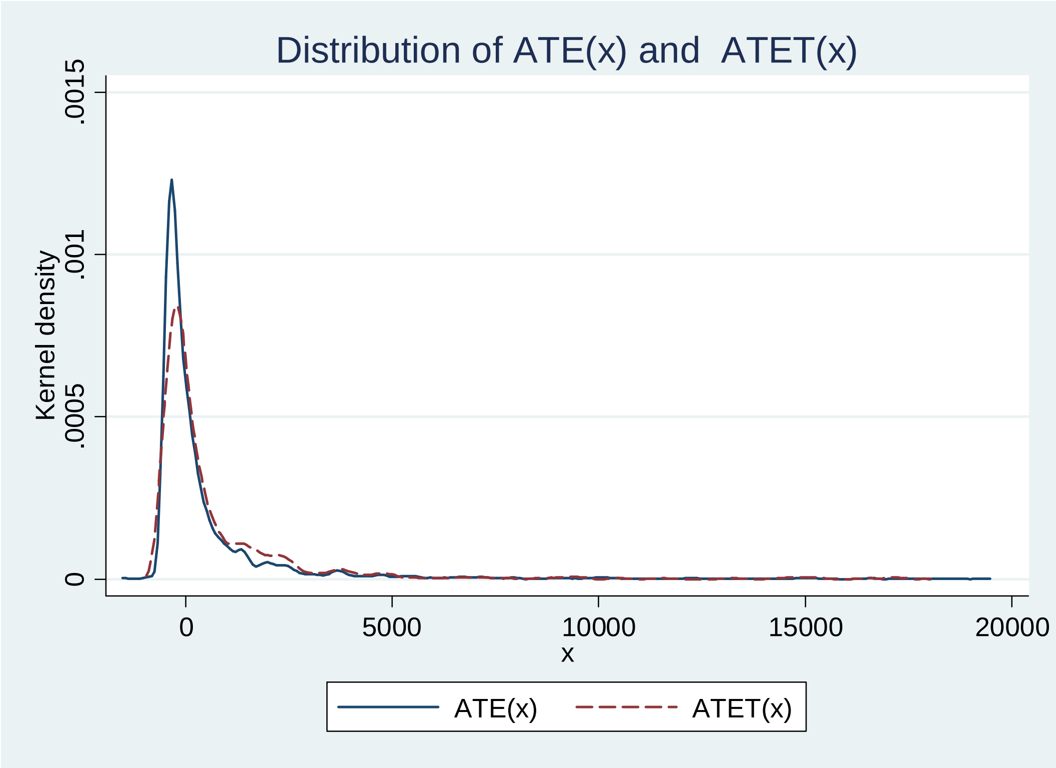


TABLE 9. Distributional features of the ATET(**x**).

ATET(**x**)	
Obs	853
Mean	878.30
Median	≈ 0
Std. Dev.	3187
Min	-971
Max	41281

TABLE 10. Average treatment effect on treated (ATET): OLS comparison for small and medium enterprises (SMI) (< 250 Size), large (>250), very large (>500); results on sectoral, regional and time dummies omitted; standard errors in parentheses; * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Thousand Euros.

Dep. Var.: Firm own R&D expenditure	(1) SMALL <50	(2) MEDIUM >50 & <250	(3) SME <250	(4) LARGE >250	(5) VERY LARGE >500
Treatment(t)	-174.05	70.00	101.24	1148.59*	2273.50**
	(125.45)	(141.98)	(138.45)	(607.15)	(1045.15)
Knowledge	-82.69	82.88	133.30	104033.24***	106828.48***
	(312.79)	(389.80)	(140.67)	(21732.52)	(23138.66)
Leverage	-12.34	188.76***	86.14*	31.06	-6.87
	(19.42)	(68.80)	(46.67)	(55.83)	(264.94)
Cash-flow	70.47	951.69*	273.59	-3789.42**	-6605.69**
	(147.42)	(509.76)	(169.77)	(1787.77)	(2651.60)
Equity	60.37	674.67	22.36	1272.50*	-232.36
	(54.17)	(417.19)	(71.66)	(736.39)	(1046.37)
Labour-cost	99.99	-1525.81***	76.49	-3514.24**	-1859.12
	(282.11)	(554.20)	(323.95)	(1762.88)	(3795.70)
Capital Intensity	-37.72	8.25	189.83*	-1505.64***	-449.14
	(173.42)	(324.09)	(112.73)	(578.11)	(732.24)
Size	11.93***	6.86***	8.52***	3.62***	3.30***
	(4.54)	(1.00)	(1.04)	(0.46)	(0.52)
Only Art.14	100.05	-428.07**	-335.82**	dropped	dropped
	(148.00)	(170.55)	(147.04)		
Objective 1	-332.19	488.37	-12.32	6807.71**	9201.00***
	(444.45)	(356.40)	(309.22)	(2977.24)	(3557.85)
Collaboration	339.22	-837.71	599.82	10381.63***	14295.03***
	(305.05)	(1171.66)	(524.52)	(3548.07)	(5029.32)
Subsidy allocation	18.00	746.07**	405.05*	5397.01	2956.78
	(144.39)	(305.26)	(209.93)	(4670.41)	(5287.58)
N	1053	1814	2867	1133	644
adj. R^2	0.108	0.525	0.285	0.491	0.468
r2	0.16	0.54	0.30	0.52	0.52
F	n.a.	n.a.	n.a.	14.71	n.a.
ll	-9183.03	-16365.72	-26057.26	-11824.64	-6847.02

TABLE 11. Average treatment effect on treated (ATET): OLS comparison for High, Medium and Low tech enterprises; results on sectoral, regional and time dummies omitted; standard errors in parentheses; * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Thousand Euros.

Dep. Var.: Firm own R&D expenditure	(1) High	(2) Medium	(3) Low
Treatment(t)	427.17	266.83	868.32**
	(633.75)	(213.05)	(339.66)
Knowledge	93200.62***	3047.91	497.16
	(6960.00)	(2462.45)	(3052.91)
Leverage	-86.77	49.24	-4.83
	(208.78)	(42.53)	(168.15)
Cash-flow	-1013.09	-346.52*	485.82
	(674.02)	(201.96)	(1565.20)
Equity	64.46	246.91**	-95.59
	(177.91)	(113.78)	(308.90)
Labour-cost	-2585.50	-1115.43**	1083.88
	(2106.77)	(512.14)	(1437.85)
Capital Intensity	-237.49	-312.83	689.61
	(946.69)	(533.86)	(638.47)
Size	5.75***	4.42***	3.97***
	(0.30)	(0.11)	(0.17)
Only Art.14	-3306.47**	-460.68	-431.40
	(1517.44)	(455.27)	(765.38)
Objective 1	8085.20***	1462.07*	-4184.89***
	(1928.48)	(801.53)	(1526.92)
Collaboration	14299.08***	-13.56	2346.56
	(1980.74)	(2031.81)	(2278.93)
Subsidy allocation	3809.93**	-101.33	837.95
	(1573.95)	(701.80)	(1902.57)
Mean emp.	403	326	317
N	1001	1861	366
N. of treated	238	387	81
adj. R^2	0.512	0.528	0.636
r2	0.53	0.54	0.67
F	31.00	52.92	18.23
ll	-10301.03	-17666.94	-3317.55

TABLE 12. Average treatment effect on treated (ATET): OLS comparison by Italian macro-regions; results on sectoral, regional and time dummies omitted; standard errors in parentheses; * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Thousand Euros.

Dep. Var.: Firm own R&D expenditure	(1) North	(2) Center	(3) South
Treatment(t)	735.90**	1588.83***	-1105.99
	(293.30)	(550.86)	(1630.86)
Knowledge	561.96	1521.80	-3109.81
	(463.27)	(1993.52)	(3042.30)
Leverage	94.38	-20.38	20.40
	(59.81)	(61.65)	(51.49)
Cash-flow	9.34	-39.81	653.43
	(264.94)	(628.28)	(409.01)
Equity	86.24	-141.17	-52.11
	(100.58)	(177.01)	(333.10)
Labour-cost	-544.31	77.09	799.79
	(533.16)	(1381.02)	(519.54)
Capital Intensity	162.61	140.86	-2371.62**
	(116.32)	(898.72)	(1170.16)
Size	4.04***	4.62***	7.75***
	(0.12)	(0.28)	(0.50)
Only Art.14	-1657.76**	-3065.68***	-12762.22***
	(681.94)	(963.92)	(3036.42)
Objective 1	5430.52***	-3866.05***	859.32
	(1000.40)	(1431.11)	(1572.21)
Collaboration	9878.90***	12034.62***	4037.87*
	(1085.33)	(1968.37)	(2262.10)
Subsidy allocation	2362.08**	3152.82***	20188.93***
	(919.52)	(1055.99)	(2759.20)
N	3004	754	242
N. of treated	605	189	59
adj. R^2	0.374	0.446	0.680
r2	0.39	0.48	0.74
F	32.51	13.13	12.15
ll	-30191.76	-7461.40	-2351.45

TABLE 13. Average treatment effect on treated (ATET): OLS comparison according to three percentile classes of financing intensity (as subsidy share on the total project cost): w1, w2 and w3 are treatment dummy variables for low, medium and high financed firms respectively; results on sectoral, regional and time dummies omitted; standard errors in parentheses; * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Thousand Euros.

Dep. Var.: Firm own R&D expenditure	(low intensity)	(medium intensity)	(high intensity)
w1	503.74*		
	(305.20)		
w2		506.38	
		(484.65)	
w3			1890.66***
			(624.64)
Knowledge	474.27	625.58	432.04
	(414.65)	(541.50)	(405.20)
Leverage	75.78**	65.63*	43.60
	(38.52)	(38.08)	(33.67)
Cash-flow	165.11	193.78	308.05
	(197.25)	(238.34)	(236.88)
Equity	46.94	51.99	34.57
	(77.48)	(81.76)	(77.78)
Labour-cost	-70.19	-97.87	192.93
	(390.90)	(458.40)	(435.65)
Capital Intensity	132.94	150.56	153.19
	(93.70)	(95.78)	(93.91)
Size	3.50***	3.63***	3.88***
	(0.37)	(0.37)	(0.40)
Only Art.14	dropped	dropped	dropped
Objective 1	312.71	2985.69	1064.51
	(1542.82)	(1897.94)	(1579.60)
Collaboration	7968.01***	12268.31**	5523.92*
	(2584.57)	(5168.28)	(3290.55)
Subsidy allocation	4012.15	6819.81*	11055.01**
	(3007.59)	(3656.54)	(4604.12)
N	3358	3387	3376
adj. R^2	0.323	0.336	0.371
r2	0.34	0.35	0.38
F	n.a.	11.12	11.58
ll	-33294.92	-33747.71	-33791.20

TABLE 14. Analysis of "single" and "mix of instruments". D1 = bottom-up research projects (Law 927), D2 = top-down research projects, D3 = bottom-up research projects (Law 488), D4 = other. Standard errors in parentheses; * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Thousand Euros.

Dep. Var.: Firm own R&D expenditure	
D1 (541)	936.00***
	(266.07)
D2 (35)	-4618.00***
	(1305.78)
D3 (157)	837.81*
	(501.25)
D4 (51)	-1977.01
	(3081.32)
D1D2 (7)	-2615.21
	(2460.99)
D1D3 (14)	75081.04***
	(3782.48)
D1D4 (34)	-216.04
	(3204.71)
D2D3 (5)	-12638.57**
	(5106.31)
D2D4 (3)	6031.46
	(4510.81)
Objective 1	1621.28**
	(721.76)
Only Art.14	-1170.69**
	(500.74)
Size	3.38***
	(0.10)
Collaboration	6494.31***
	(841.27)
Subsidy allocation	2039.00***
	(676.88)
N	3985
adj. R^2	0.441
r2	0.45
F	41.30
ll	-39700.96

TABLE 15.A. Structural characteristics of the crowding-out group.

	N	mean	median	min	max	cv	skewness	kurtosis
Average Treatment Effect on Treated	426	-294	-300	-971	-6.6	-0.55	-0.31	3.1
N. of Employees	426	74	65	0	289	0.65	0.8	4.1
Turnover	426	43206	13	0.11	1.60E+07	18	21	424
Turnover per capita	424	69	0.18	0.0063	1970	2.8	4.7	34
R&D intra-muros exp.	426	1082	378	0	35045	2.8	7.5	70
R&D per employee	424	21	6.5	0	1577	3.9	16	288
N. of patents	179	1.3	1	0	15	1.7	3.4	17
Patents (capitalized exp. at book value)	426	0.011	0.00072	0	0.62	4.2	9	103
Cash-flow 1	426	-0.0041	0.0055	-1.1	0.55	-30	-4.4	34
Cash-flow 2	426	-0.057	0.0053	-5.5	2.9	-8.9	-6.3	61
Leverage 1	426	0.63	0.67	0.013	1.9	0.32	-0.0034	5.9
Leverage 2	426	1.1	0.65	0.0051	57	2.9	13	200
Equity 1	426	0.24	0.086	0.00075	6.7	2.6	6.2	48
Equity 2	426	0.11	0.082	0.00084	0.82	0.99	2.4	12
Labour costs	426	0.33	0.23	0	6.7	1.7	8.8	95
Capital intensity	426	0.068	0.033	0	0.55	1.4	2.3	9
(Current Assets-Current Liabilities) / Total Assets	424	-0.34	-0.36	-1.5	0.64	-0.9	0.67	4
Retained Earnings / Total Assets	426	-0.0041	0.0055	-1.1	0.55	-30	-4.4	34
ROI (Return on investment)	426	0.034	0.04	-1	0.33	3.5	-4	33
Book Value of Equity / Total Liabilities	426	0.79	0.31	-0.52	73	4.7	18	343
Turnover/ Total Assets	426	0.98	0.95	0.012	3	0.46	0.76	4.8
Altman z-score (risk indicator)	424	2.7	2.8	0	4	0.15	-1.4	13
Return to R&D	380	15	0.027	0.0001	944	4.7	8.2	89
Subsidy share on total project costs	273	0.47	0.46	0.0046	1	0.32	0.045	4.4
OPM (opeartive profit margin)	426	-0.0036	0.043	-3.2	1.1	-92	-6.6	56
Investment rate 1 (equipment)	355	250	-0.17	-1	18508	4.4	7	67
Investment rate 2 (equipment)	382	-32	-0.002	-1238	0.31	-3.3	-6.6	61
Investment rate 3 (material assets)	387	410	-0.065	-1	40096	6.3	12	171
Investment rate 4 (material assets)	377	365	-0.065	-1	45530	6.7	15	254

TABLE 15.B. Structural characteristics of the additionality group.

	N	mean	median	min	max	cv	skewness	kurtosis
Average Treatment Effect on Treated	427	2048	779	-4.8	41281	2	5.3	40
N. of Employees	427	791	403	6.1	12270	1.6	4.8	34
Turnover	427	70985	141	0.13	8108655	6	16	306
Turnover per capita	427	81	0.23	0.0027	823	1.9	2.1	7.3
R&D intra-muros exp.	427	7678	1775	0	100587	1.9	3.6	18
R&D per employee	427	12	5.2	0	186	1.9	4.4	26
N. of patents	257	6.4	3	0	74	1.5	3	16
Patents (capitalized exp. at book value)	427	0.0067	0.00099	0	0.4	3.5	13	209
Cash-flow 1	427	0.0063	0.0076	-0.74	0.42	14	-2.6	25
Cash-flow 2	427	-0.044	0.0086	-25	0.89	-28	-20	417
Leverage 1	427	0.59	0.61	0.081	1.4	0.32	-0.28	3.3
Leverage 2	427	1	0.66	0.16	23	2	8.5	81
Equity 1	427	0.35	0.11	0	66	9.2	20	416
Equity 2	427	0.13	0.088	0	0.81	0.93	2.2	9.1
Labour costs	427	0.28	0.21	0.048	16	2.7	19	393
Capital intensity	427	0.33	0.085	0	65	9.6	20	417
(Current Assets-Current Liabilities) / Total Assets	424	-0.35	-0.36	-1.4	0.69	-0.68	0.59	5
Retained Earnings / Total Assets	427	0.0063	0.0076	-0.74	0.42	14	-2.6	25
ROI (Return on investment)	427	0.037	0.032	-0.52	0.5	2.2	-0.38	14
Book Value of Equity / Total Liabilities	427	0.71	0.42	-0.35	7.4	1.3	3.4	18
Turnover/ Total Assets	427	0.89	0.87	0.0083	2	0.41	0.26	3.4
Altman z-score (risk indicator)	424	2.8	2.8	1.6	3.9	0.11	-0.9	5.3
Return to R&D	401	33	0.063	0.00002	2775	5.4	11	155
Subsidy share on total project costs	407	0.47	0.46	0.1	0.8	0.29	0.17	2.7
OPM (opeartive profit margin)	427	-0.022	0.041	-25	0.46	-54	-20	408
Investment rate 1 (equipment)	366	1550	-0.073	-1	483117	16	19	363
Investment rate 2 (equipment)	372	-73	-0.0032	-2144	0.92	-3.1	-5.3	35
Investment rate 3 (material assets)	373	359	-0.029	-1	4.60E+04	7.3	15	261
Investment rate 4 (material assets)	371	1668	-0.046	-1	496572	15	19	364

TABLE 16. Output additionality (pooled and by technology): only treated units. Standard errors in parentheses; * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Dep. Var.: number of filed patents	Pooled	High	Medium	Low
Own R&D (NN)	0.0221	0.0199	0.0314	0.2733**
	(0.0181)	(0.0209)	(0.0682)	(0.1228)
Subsidy	0.0871	-0.0477	1.7072***	-0.0444
	(0.0637)	(0.1019)	(0.3026)	(0.1522)
Additionality	**0.0354*** **	**0.0261** **	**0.0794*** **	**0.3135*** **
	(0.0090)	**(0.0104)**	**(0.0156)**	**(0.1147)**
Size	0.0000	0.0006*	-0.0007***	0.0053***
	(0.0001)	(0.0003)	(0.0001)	(0.0019)
N. of treated	344	114	165	31
Pseudo R^2	0.40	0.37	0.49	0.55
ll	-922.4168	-376.0032	-331.9480	-29.7126

FIGURE 2. The link between the R&D policy, technological and economic outcomes.

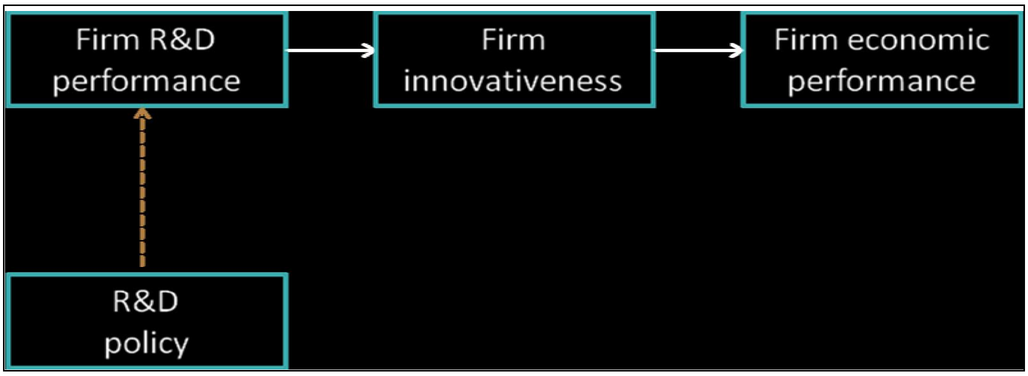
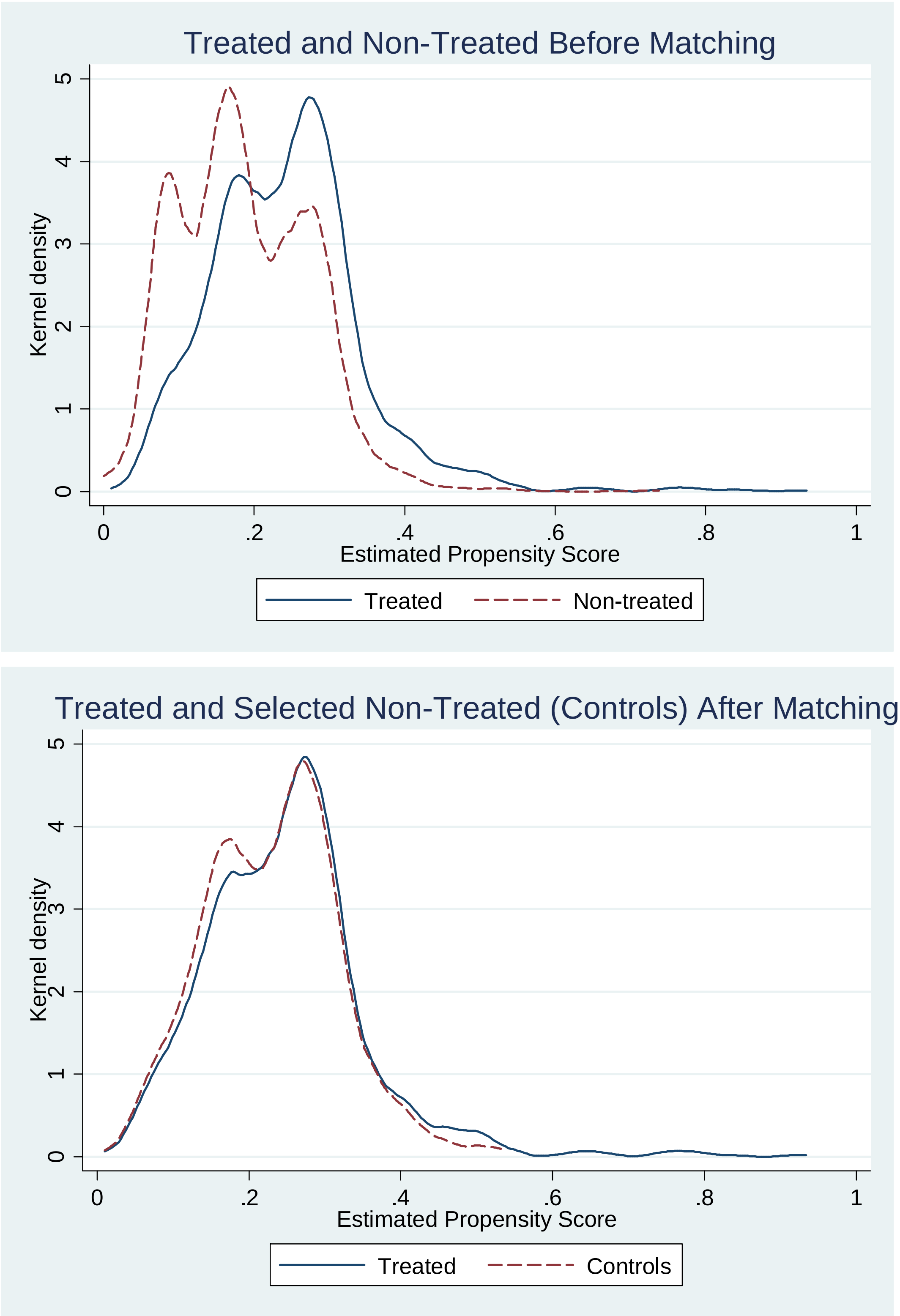


FIGURE 3. Propensity scores distribution of treated and untreated units according to the covariates of table 6.



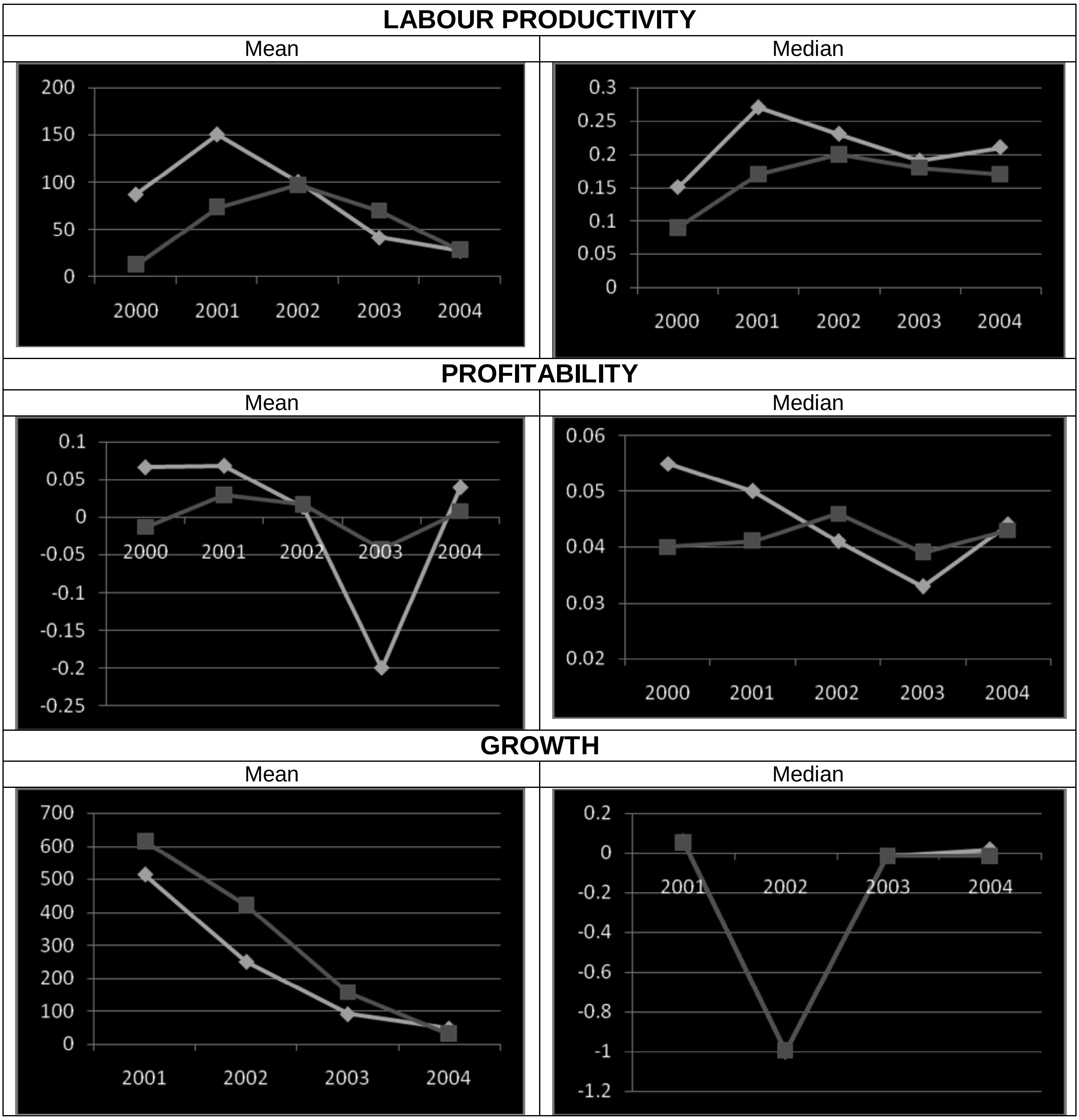


FIGURE 4. Temporal pattern of firm economic performance (productivity, profitability and growth) in the additionality and crowding-out group. Note: the black line is for the additionality and the grey line is for the crowding-out group.